Termografi anvendt indenfor forbrændingsteknik

Clausen, Sønnik

Publication date:
2009

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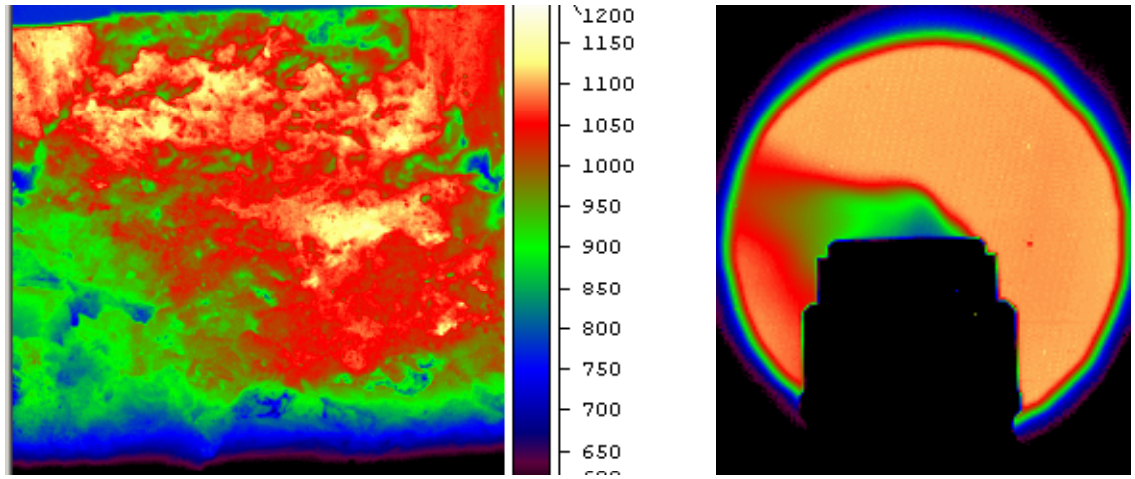

Risø DTU

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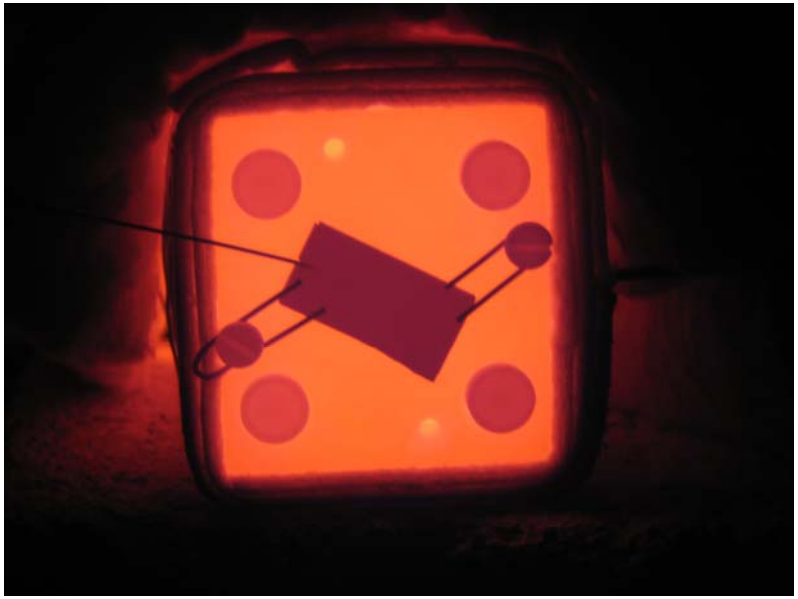
sqcl@risoe.dtu.dk

INFRARØD TEMPERATUR

- NMI, Danish reference temperature laboratory
- Accredited measurements: temperature, emissivity (ISO 17025)
- range -196ºC – 2500ºC (-80ºC – 1600ºC)

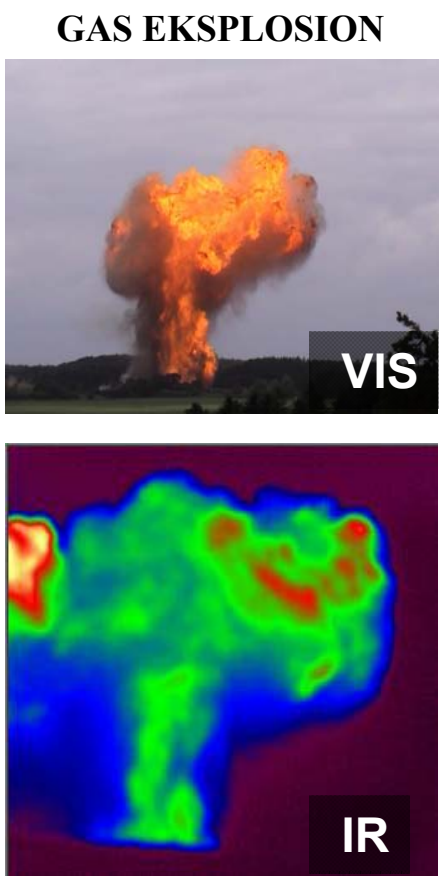


Rockwool, DONG Energy, Haldor Topsoe, Six Elements, TI, Force, Præcisions Teknik, Lundbeck, Radiometer, NOVO, Danfoss, MAN Diesel, Unimedical, Trevira N., Vattenfall, …

•Calibration
•Consultancy
•Assistance

Farve og temperatur

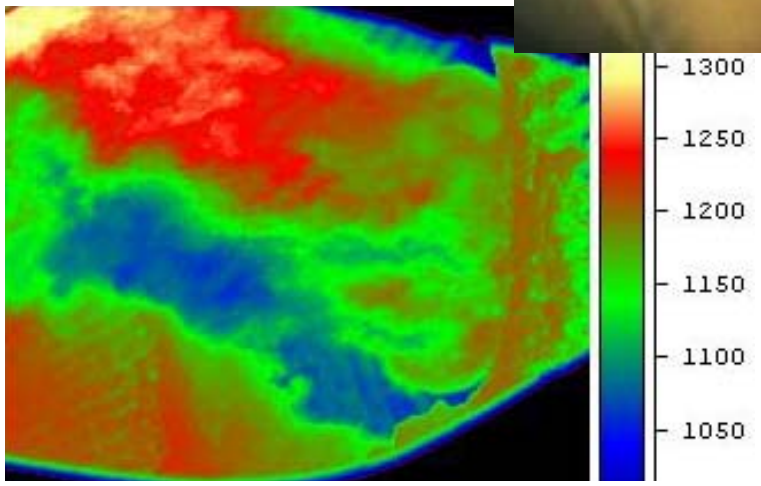
Temperatur (°C)	Farve
650 - 750	rødviolet
750 - 780	mørk karminrød
780 - 800	karminrød
800 - 830	orange/karminrød
830 - 880	mørk orange
880 - 1050	orange
1050 - 1150	gul/orange
1150 - 1250	gul
1250 - 1320	hvid/gul



Øjet ser først ved temperaturer over ca. 650°C

Optisk måling

- Kort måletid
- Berøringsløs
- Multi-måling
- …

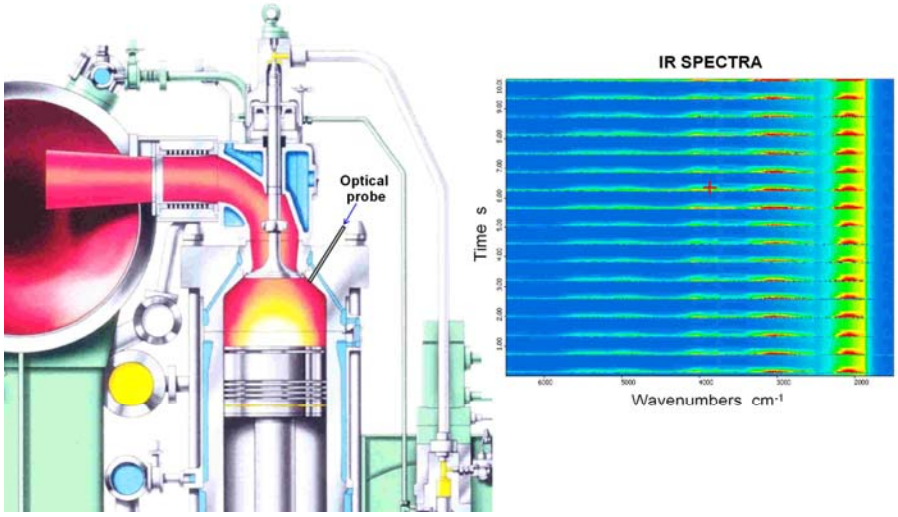


- Optisk adgang
- Kraftig absorption
- Kompleks udstyr
- Holder vindue rent
- …

OPTISKE MÅLINGER

Forskning og udvikling af optiske målemetoder med det formål at optimere eksisterende og nye forbrændings-processer, R&D nye energiteknologier, mv:

- KRAFTVÆRKER
- MOTORER
- STÅL, PROCESINDUSTRI
- R&D NYE ENERGIKILDER
- MILJØ
- ANDET



Kerne: **TEMPERATUR**

AKTIVITETER på RISØ

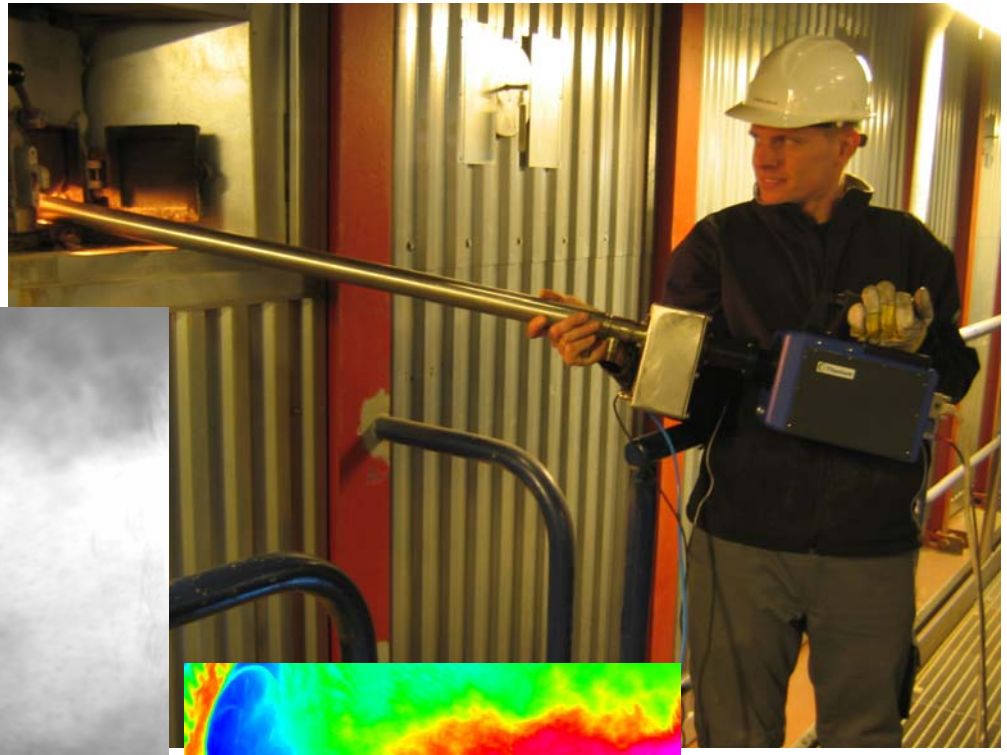
- **Forskning**: anvendt spektroskopi, målemetoder,..
- **Energiprojekter**: EU, PSO, firma,…
- **Kalibrering** af alt IR-udstyr og temperaturfølere
- **Måling** optiske egenskaber gas/overflader (ε, τ)
- **Løsning** af kunde problemer
- **Rådgivning** vedr. Termisk stråling, temperatur,…
- **Transportabelt** optisk måleudstyr

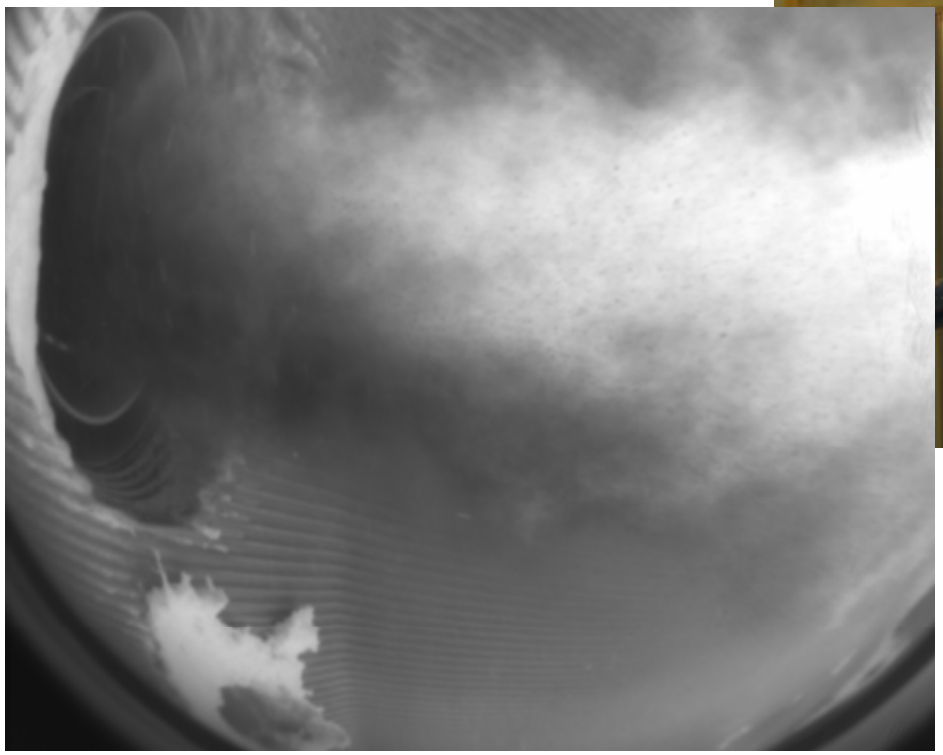
RISØ er Nationalt Reference Laboratorium for berøringsløs temperaturmåling

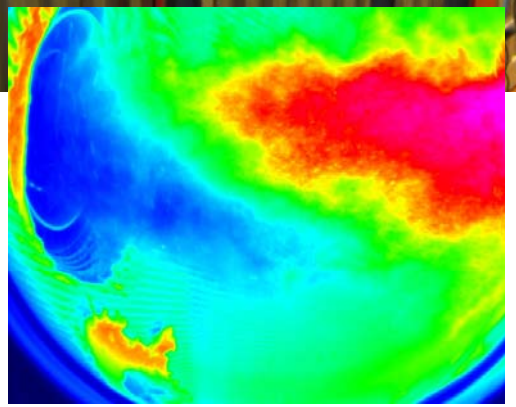
Hvad kan måles optisk?

- TEMPERATUR, VARMEFLUKS, …
- GASSAMMENSÆTNING
- PARTIKELSTØRRELSE, MÆNGDE,…
- HASTIGHEDER
- BILLEDER, VISUALISERING,…
- TILSLAGNING, UTÆTHEDER KEDEL,…

Termografering flamme

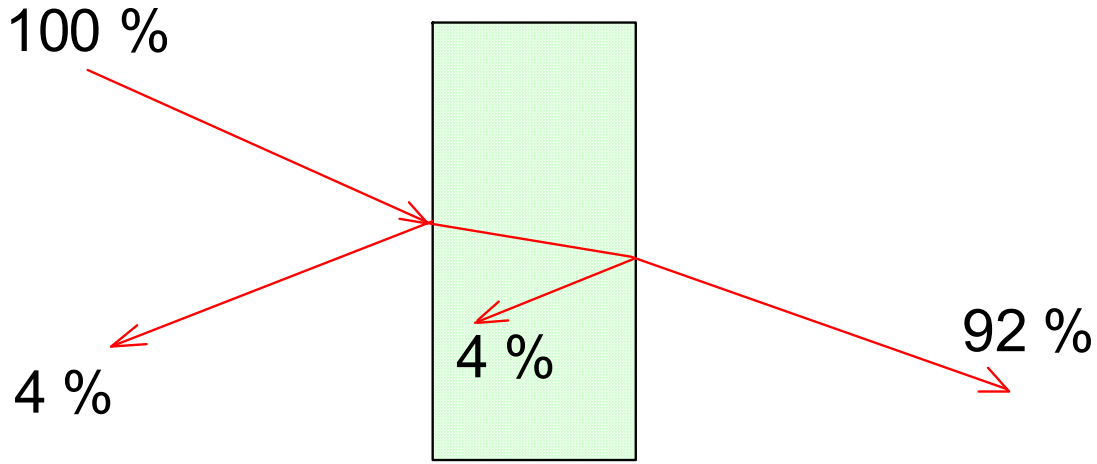




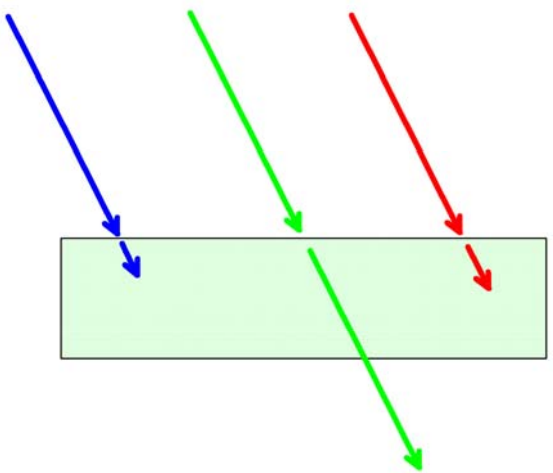


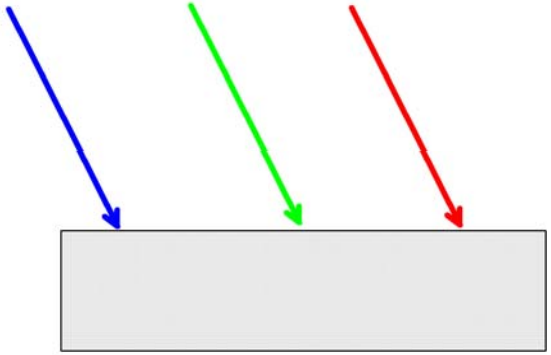
EGENSKABER af LYS

$$t + r + a + s = 1$$



ABSORPTION

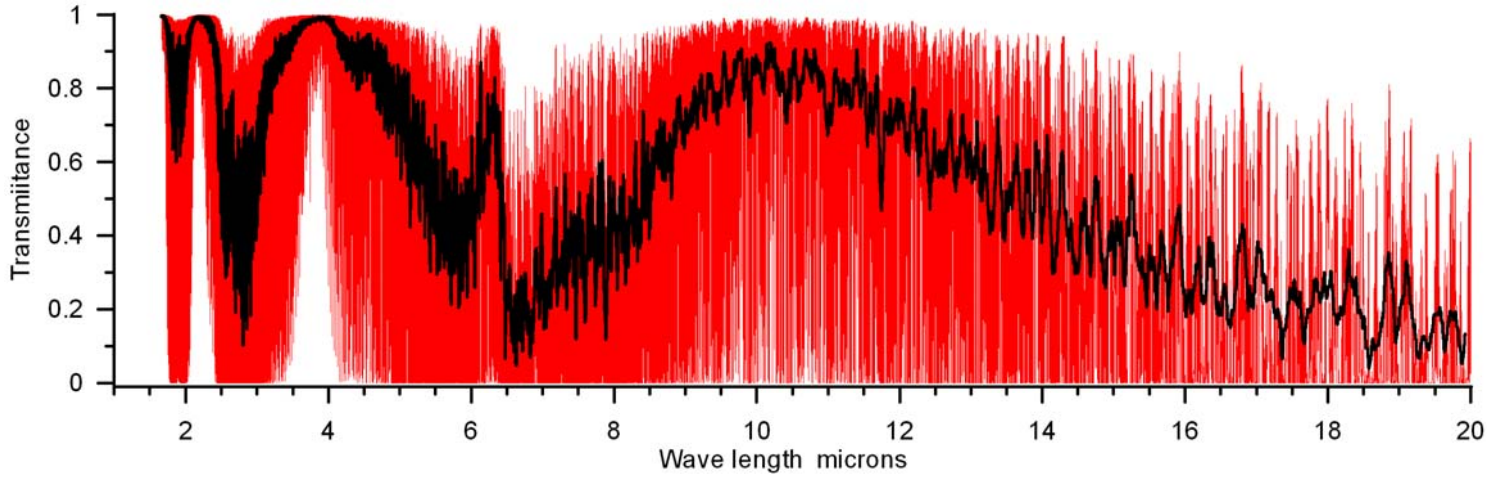


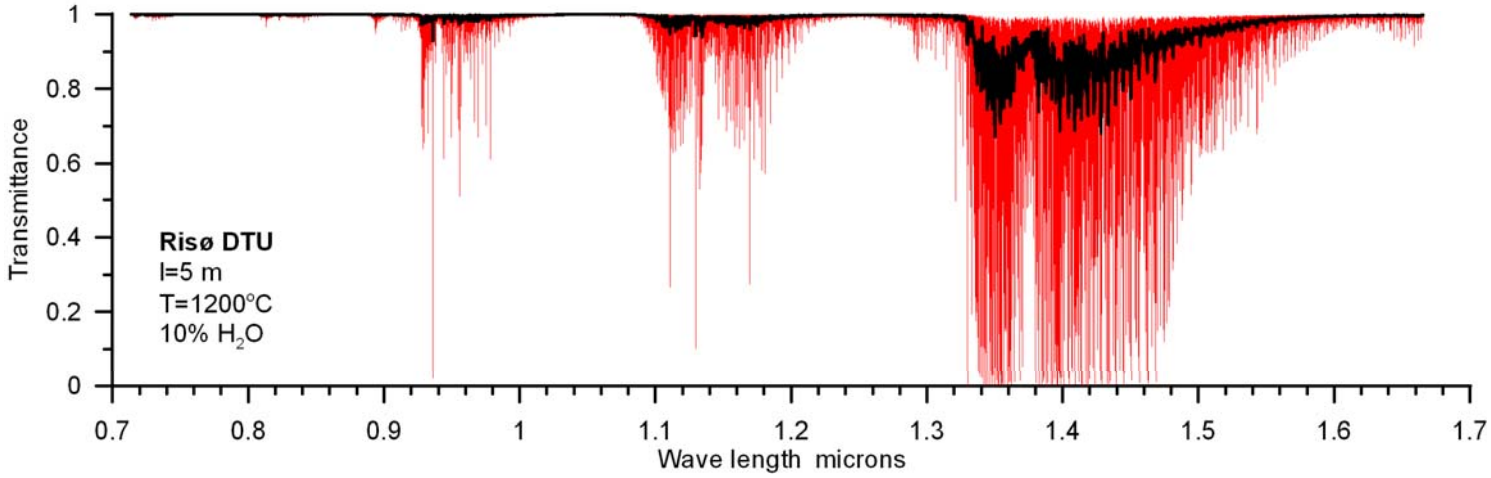


Beer's Lov:

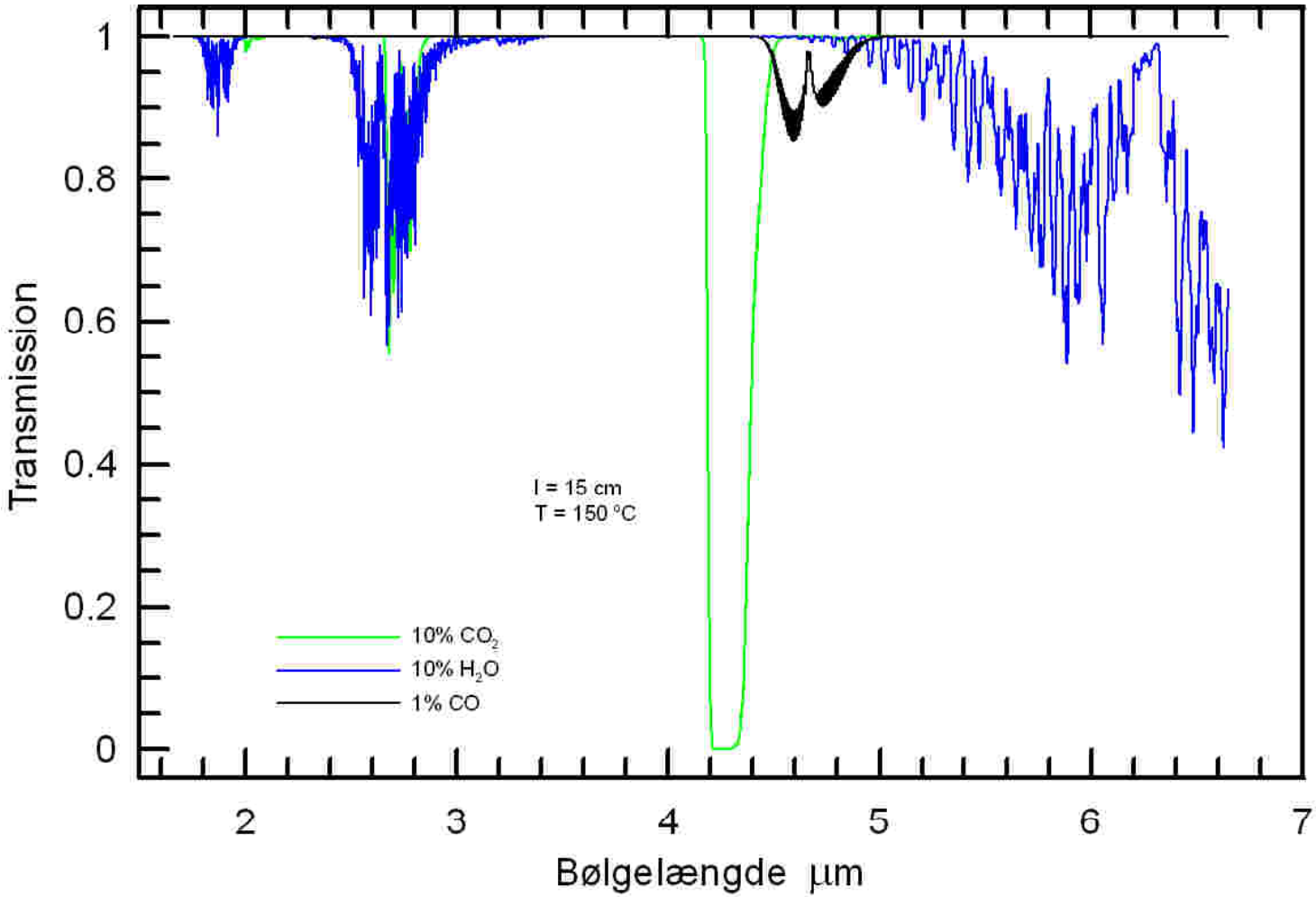
$$I = I_0 e^{-abc}$$

Absorption vand





IR absorption røggas



EMISSIVITET

Kirchhoff's lov:

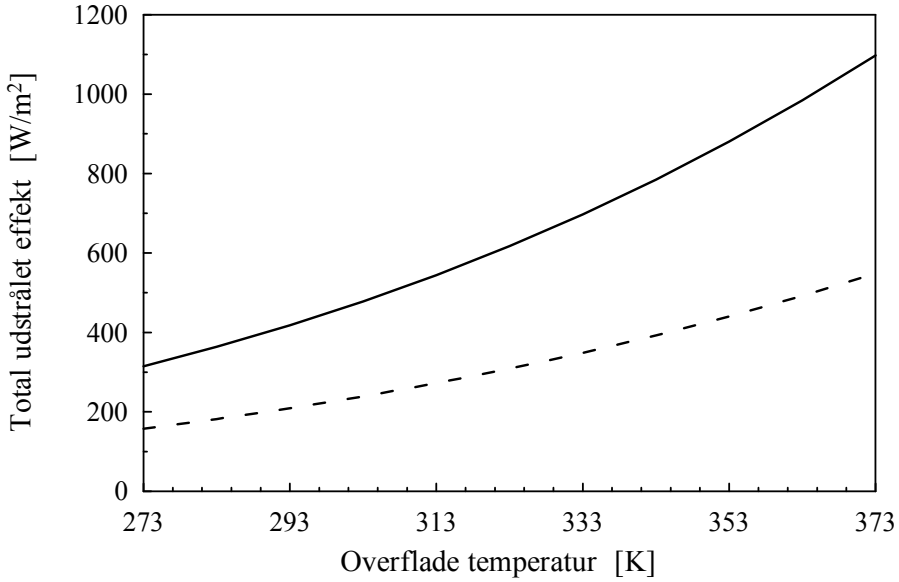
EMISSIVITET = ABSORPTION

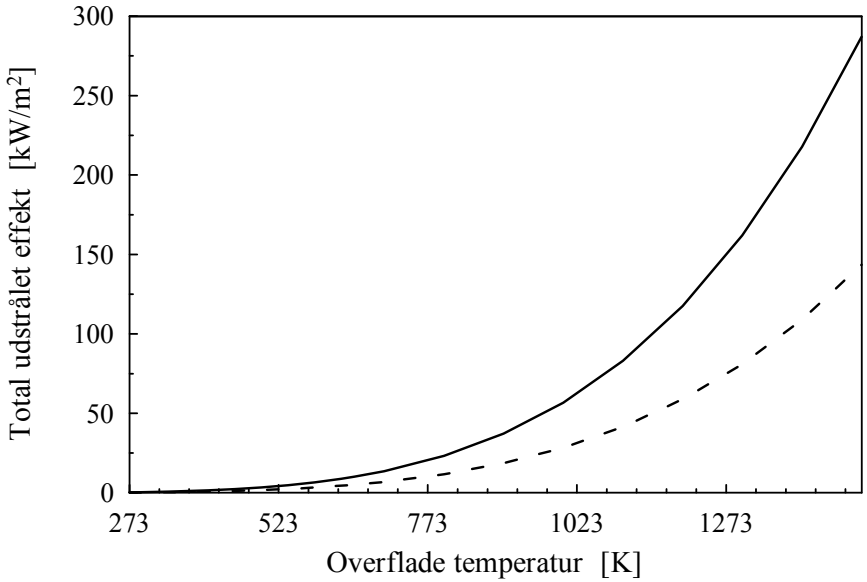
UDSTRÅLET ENERGI ABSORBERET ENERGI

Udstrålede energi fra en overflade eller gas er lig med den energi der absorberes

ε , EMISSIVITET er et tal mellem 0 og 1

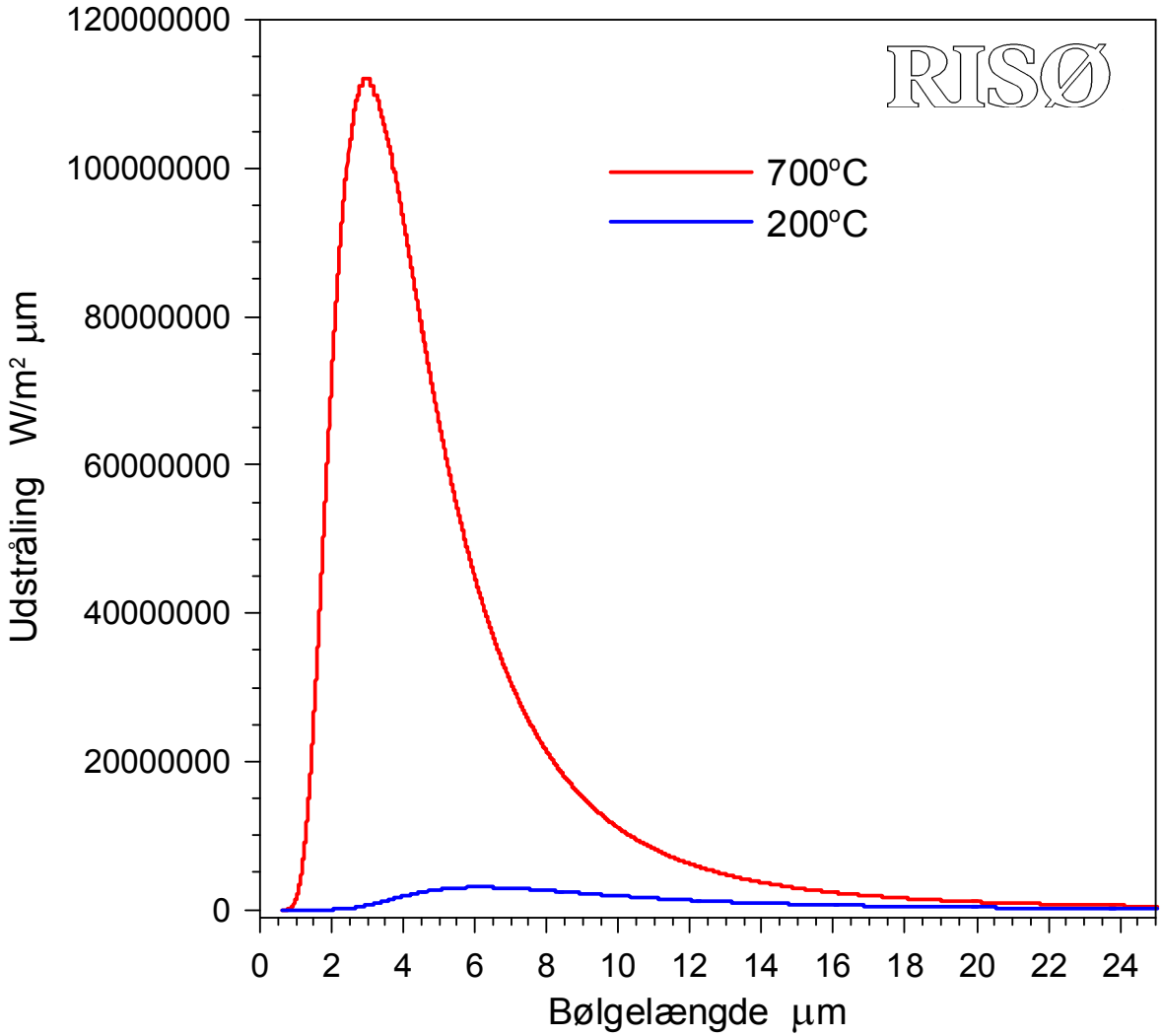
Udstrålet effekt fra overflade





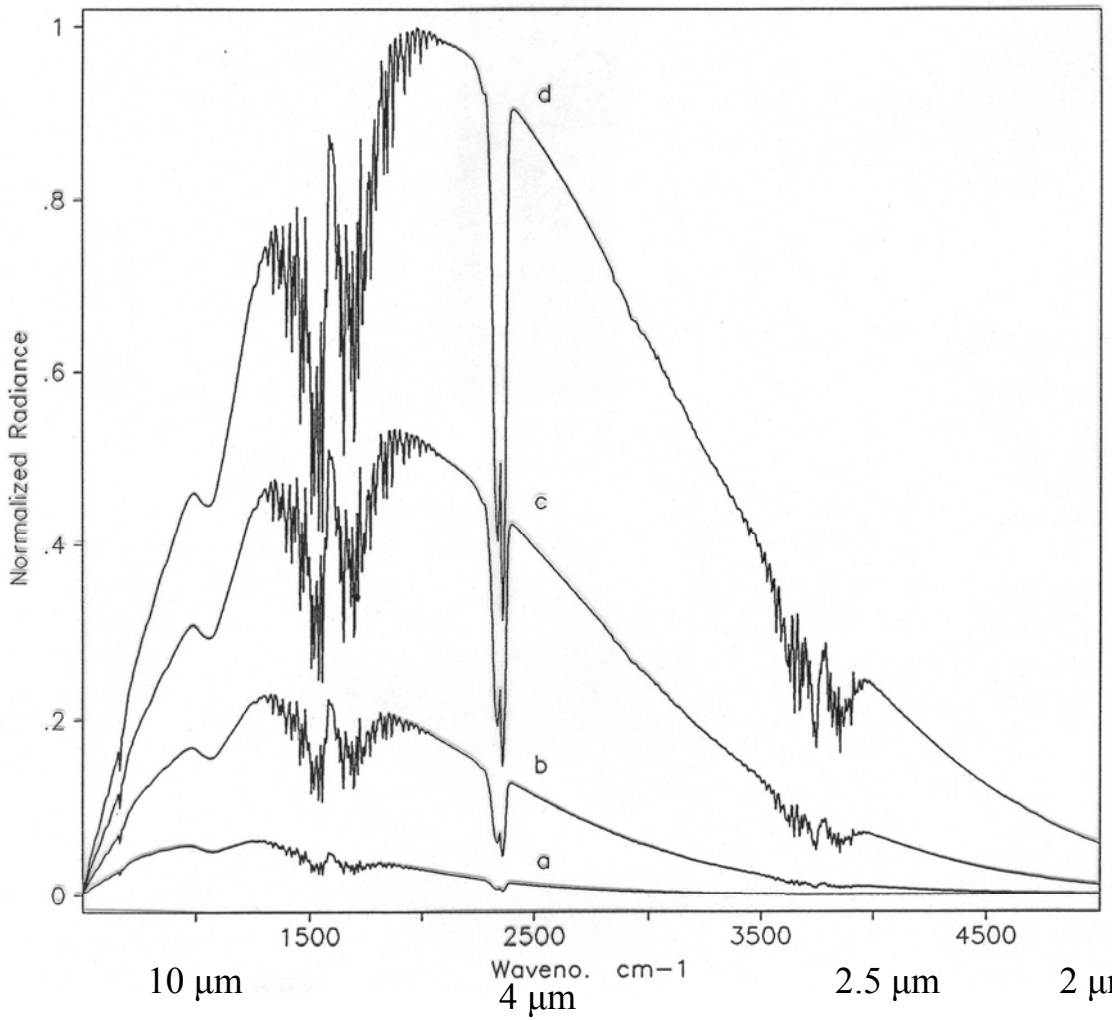
Blackbody-kurver

TEORI



Blackbody-kurver

MÅLT

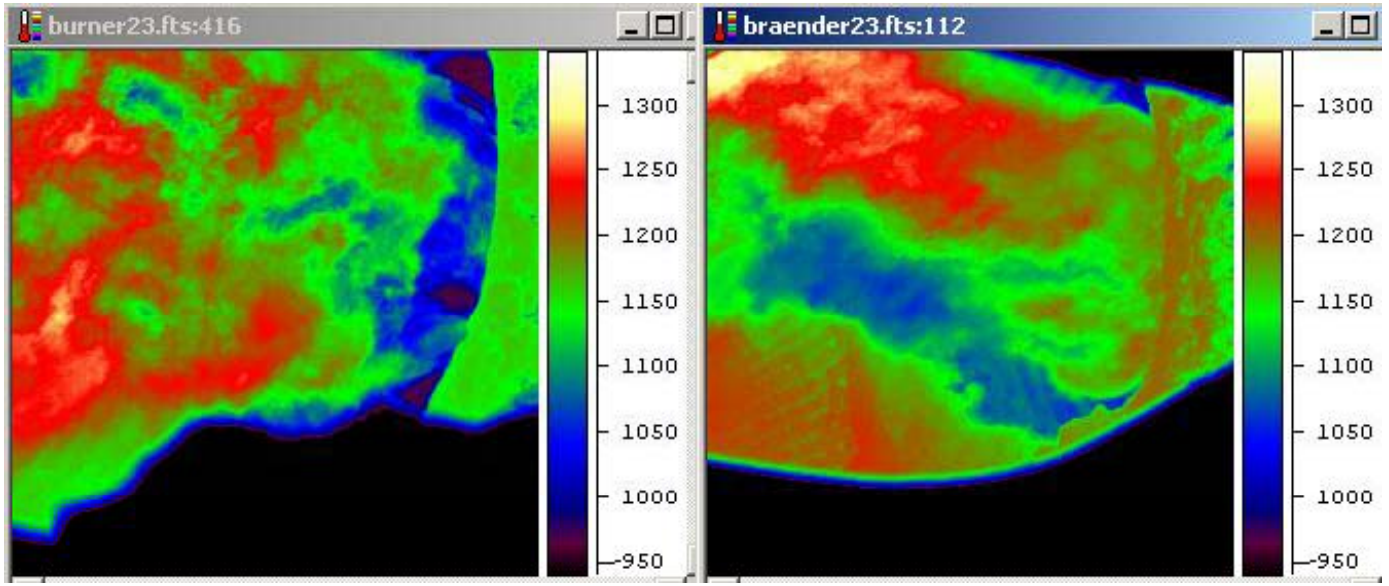


CCD versus IR-kamera

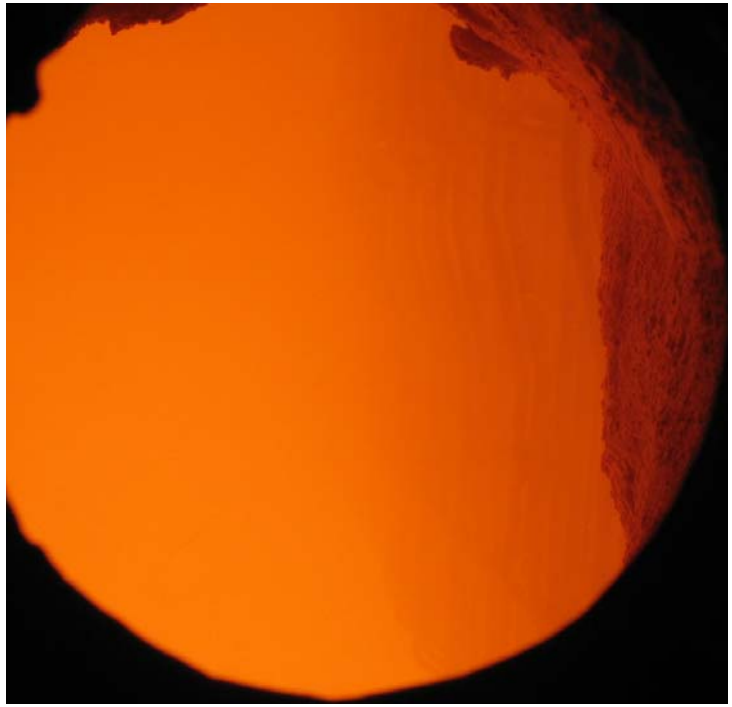
Video/CCD:

”IR ser gennem sod/flammer”

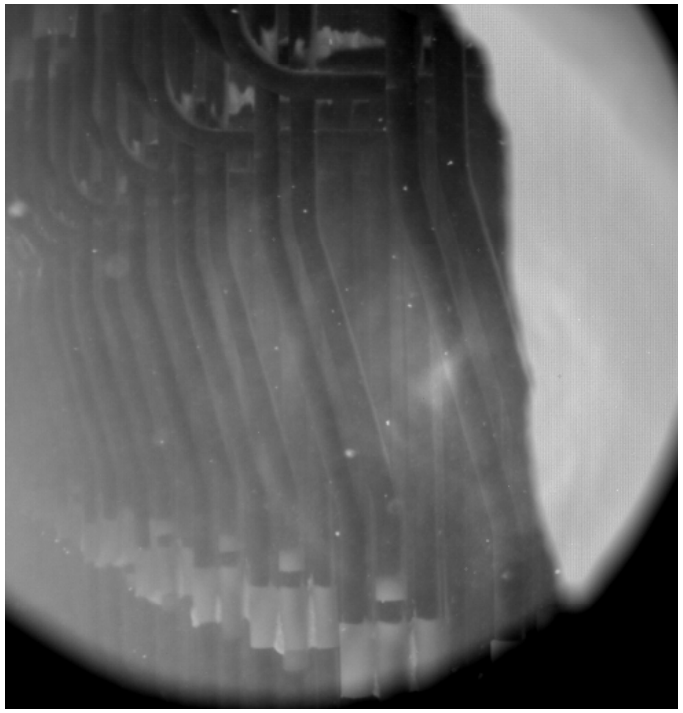
IR:



Sigtbarhed partikler

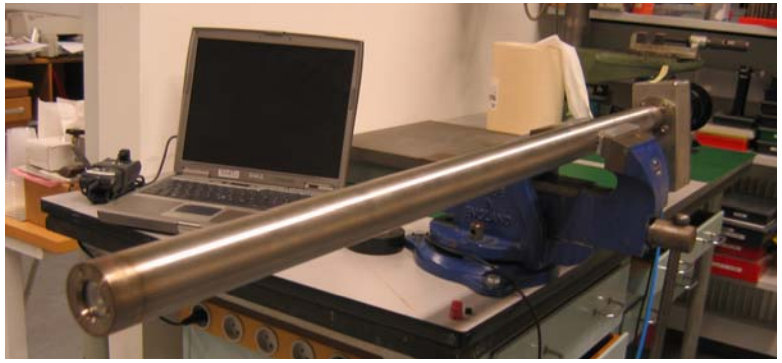


SYNLIG / VIDEO

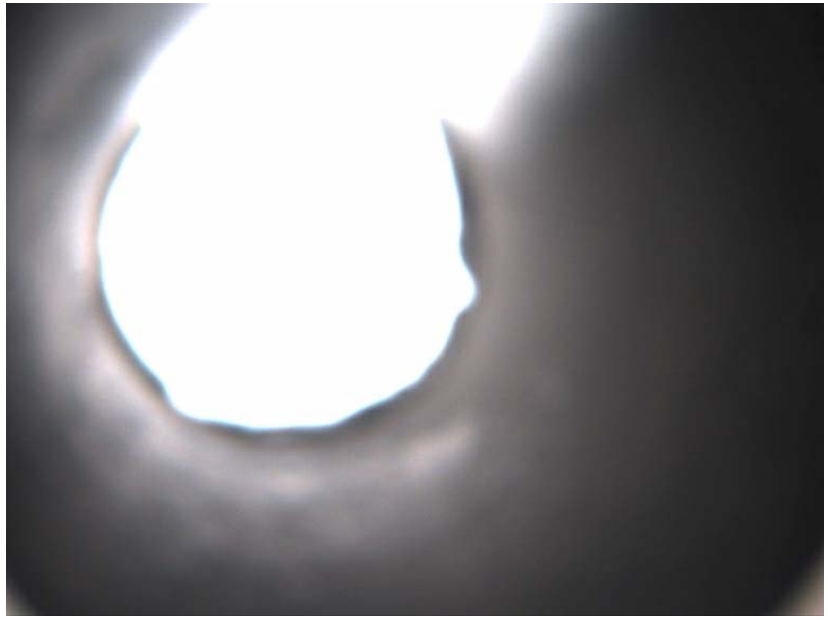


INFRARØDT

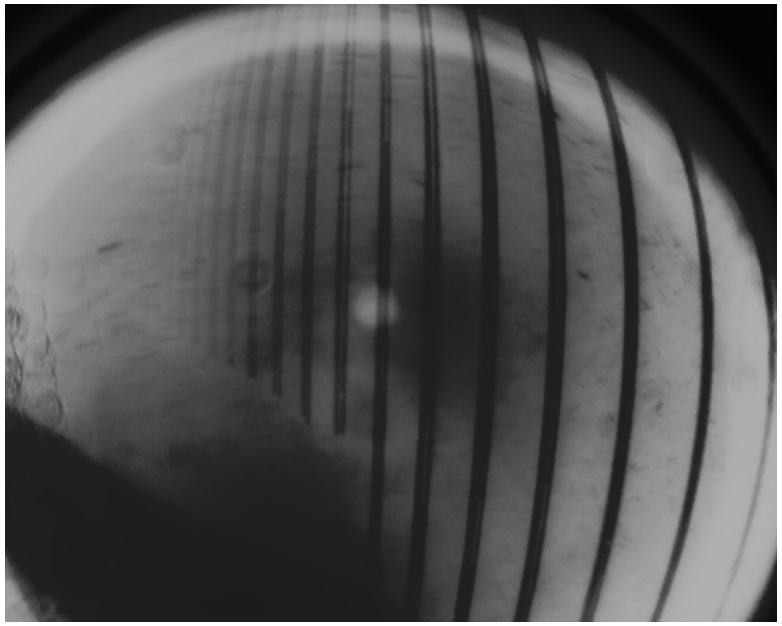
Dårlig sigtbarhed



IR-VIS Endoskop



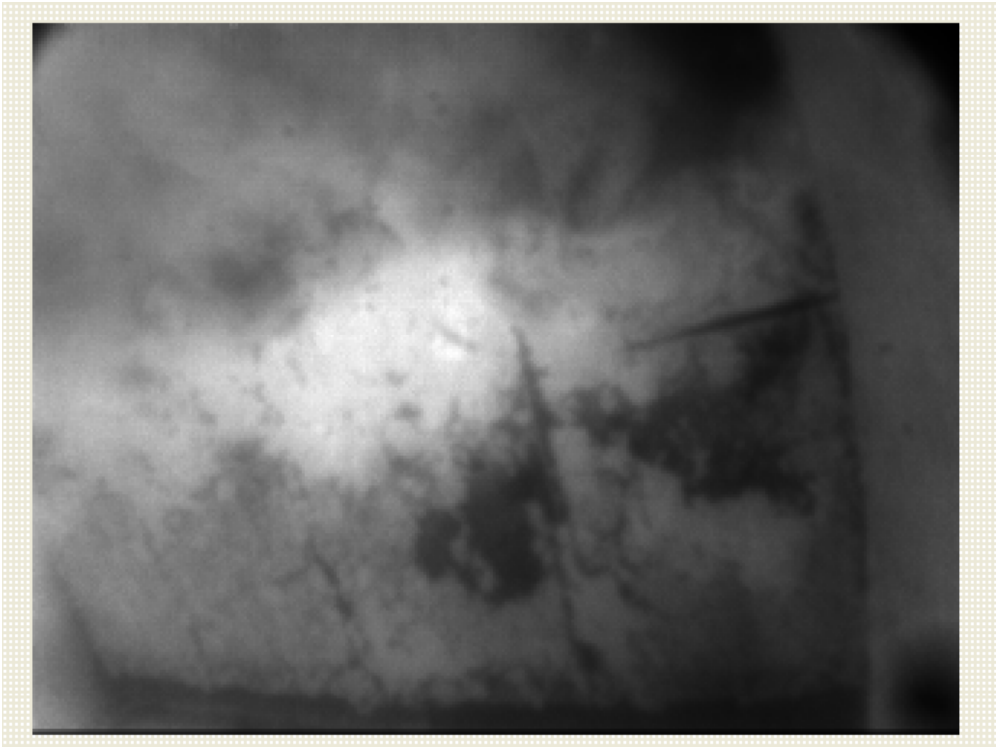
Video/CCD



IR-kamera 3.9 µm

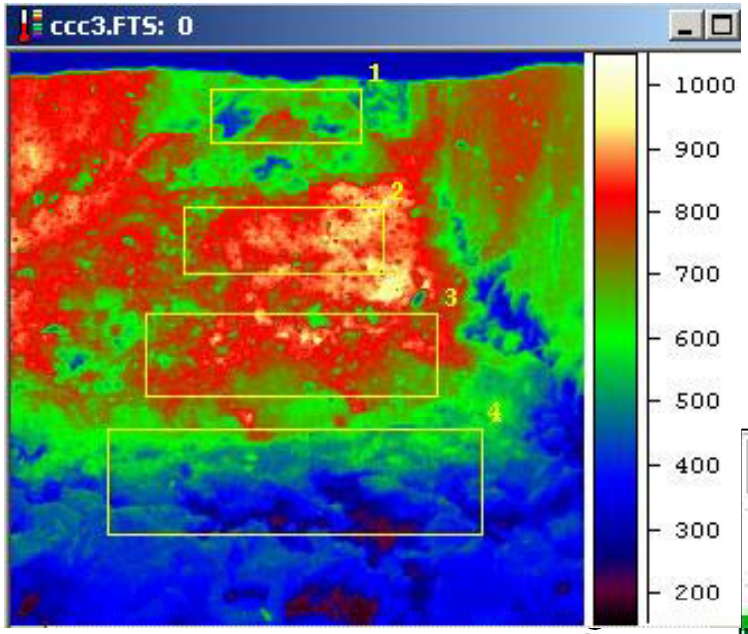
Måling på ristelag

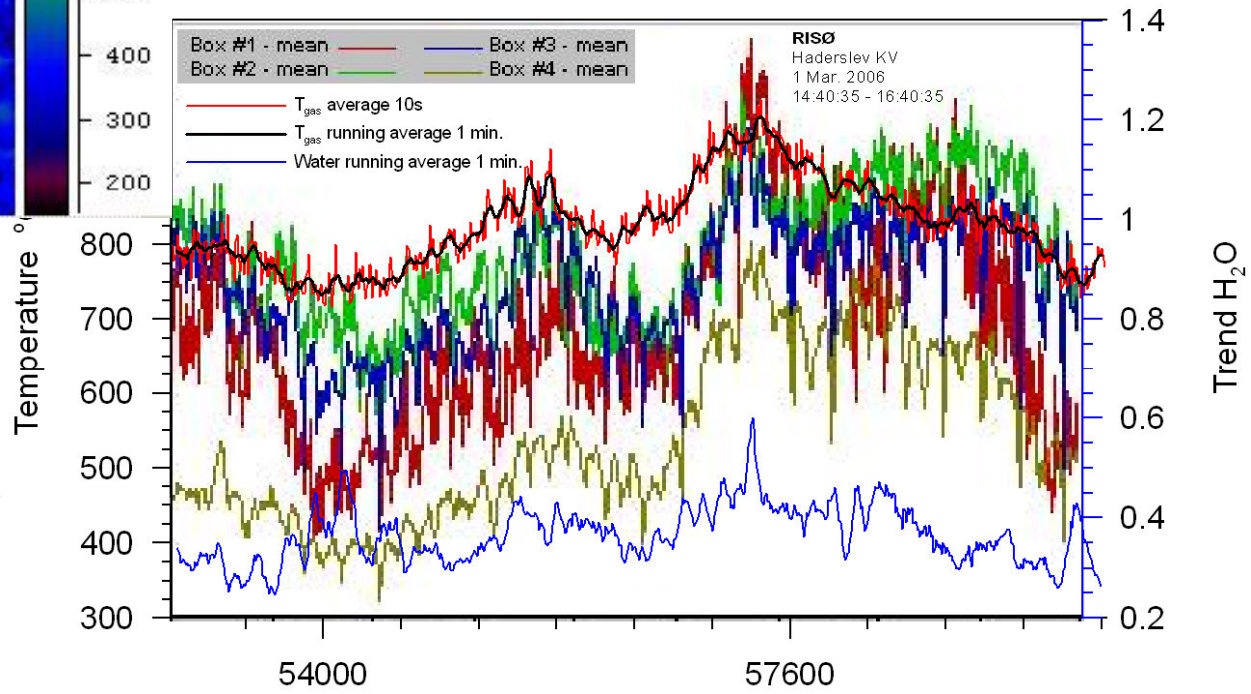
-Rist ved kedelvæg
-Indfødning
-Halmbunker opbygges
-Halm isolerer
-Sigtbarhed / halmstrå / CO
-Risteryst



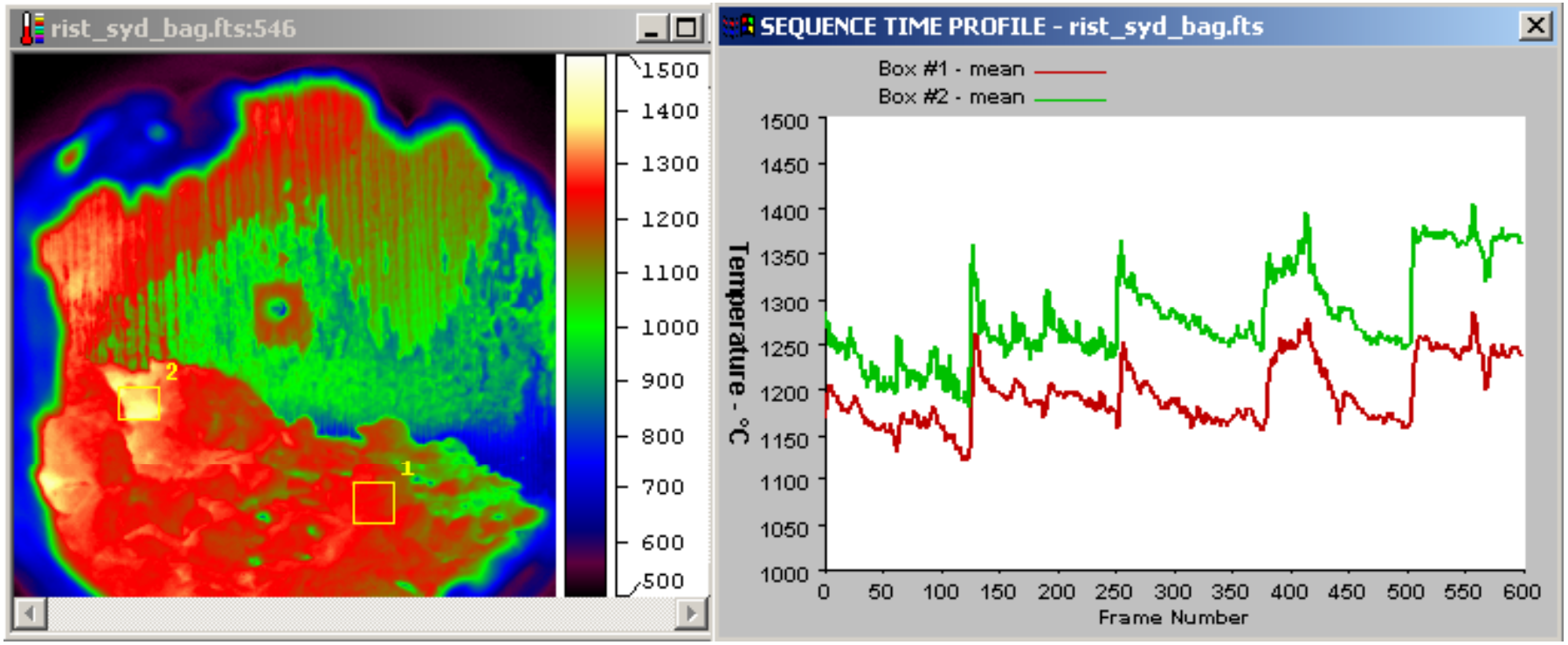
IR-kamera installeret på halmkedel AVV

Rist Haderslev KV



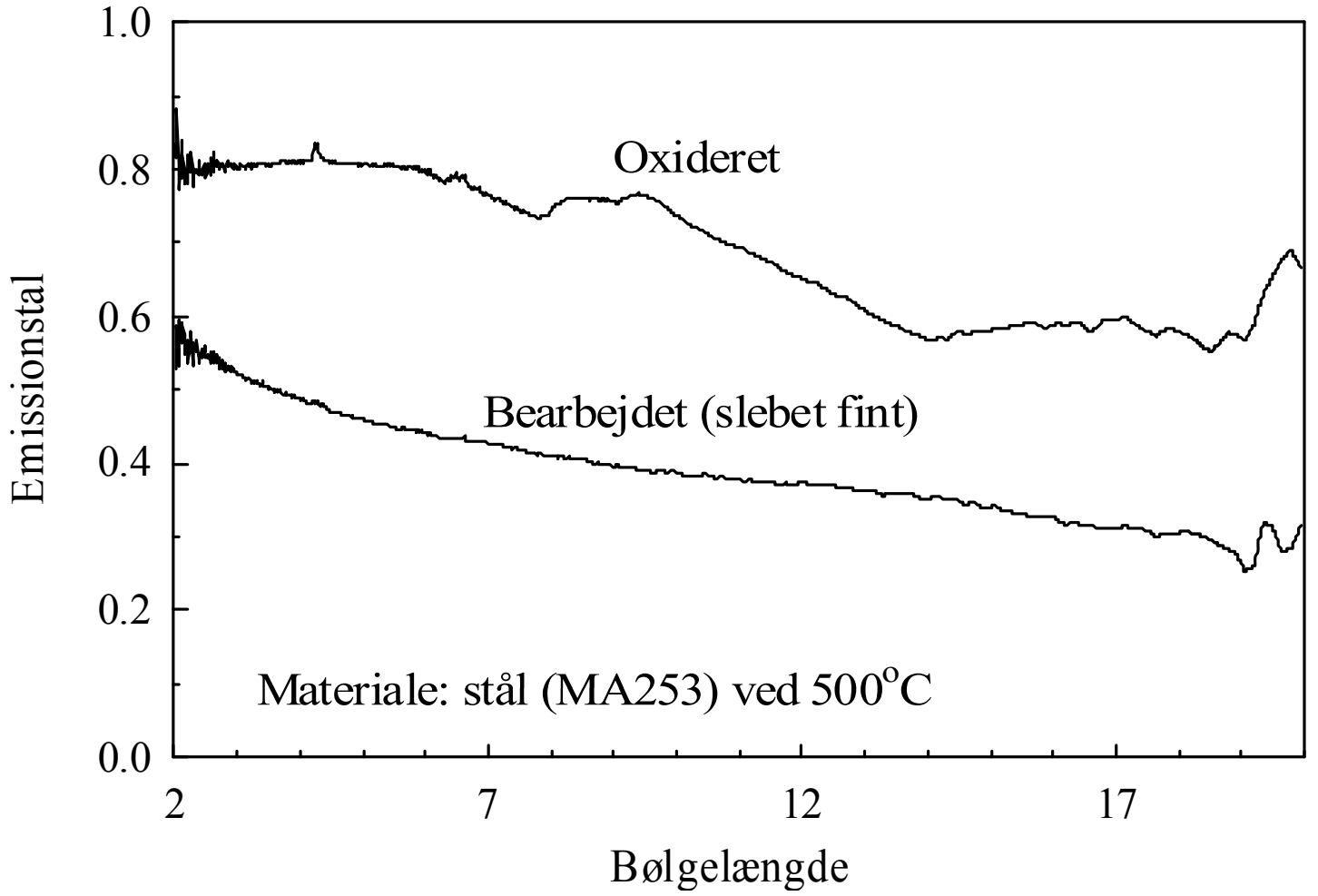


Vægtemperatur



Hurtigt og let at termografere kedelvægge på AVV halmkedel pga. måleport i siden af kedel ved slaggefald. (3.9 µm filter).

Emissivitet stål



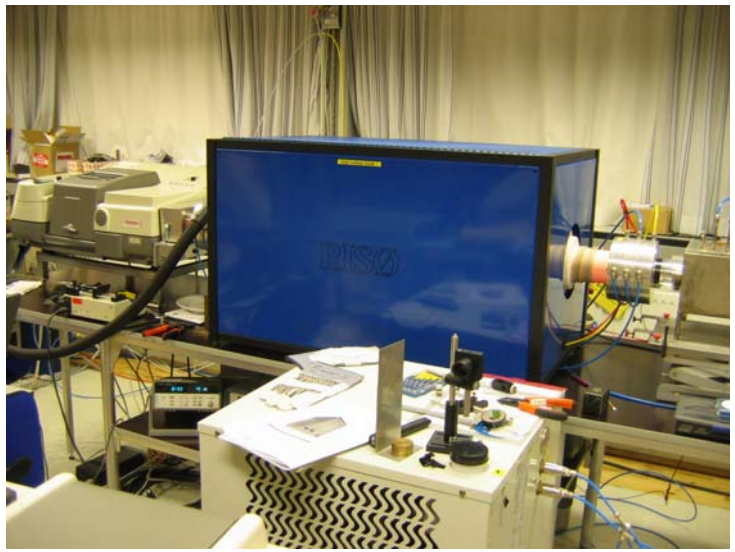
VALG AF BØLGELÆNGDE
Overfladetemperatur

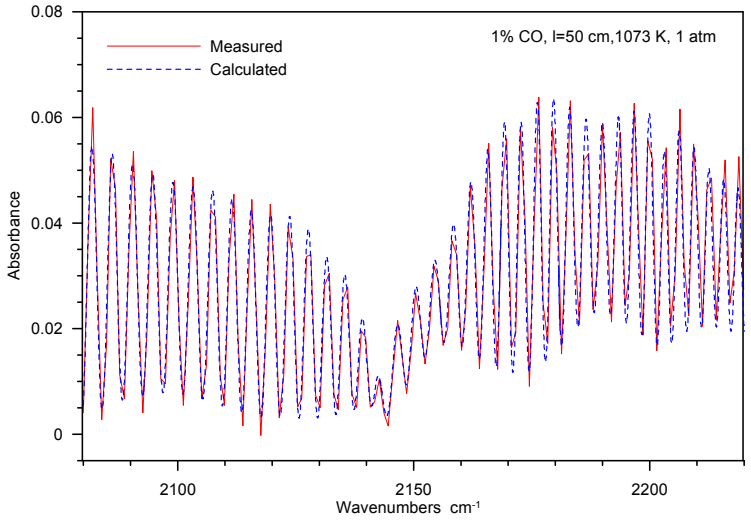
- 8-14 µm: Faste overflader, lave temperatur
- 3-5 µm: Faste overflader, lav temperatur
- 4.3 µm: CO_2
- 3.9 µm: Måling gennem varm røggas
- 3.3 µm: Detektion gas (CxHy)
- 0.5-2 µm: Højtemperatur

- Jo lavere temperatur jo mindre absolut målefejl
- Kortere bølgelængde – lavere fejl (ingen refleksion)
- Overflader med høj emissivitet – lav fejl

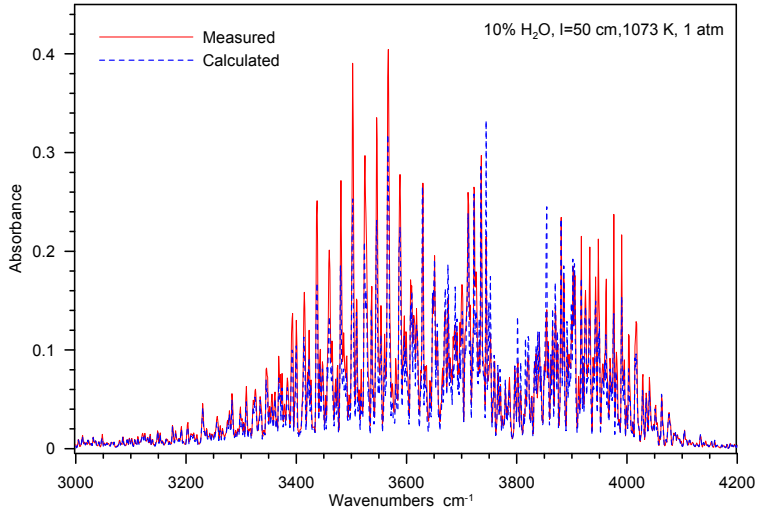
Hot Gas Cell

Test af nye gasmåleudstyr (laser, mv)
Kalibreringsdata (udvikle målemetoder)
Opbygge database (høj opløsning)
Bred anvendelse: kraftværk, miljø, fly, kemi,…



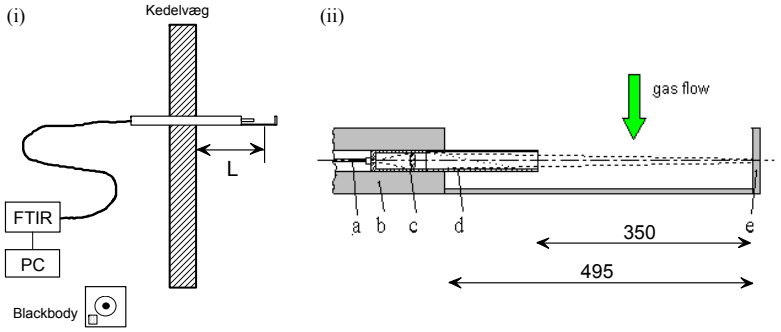


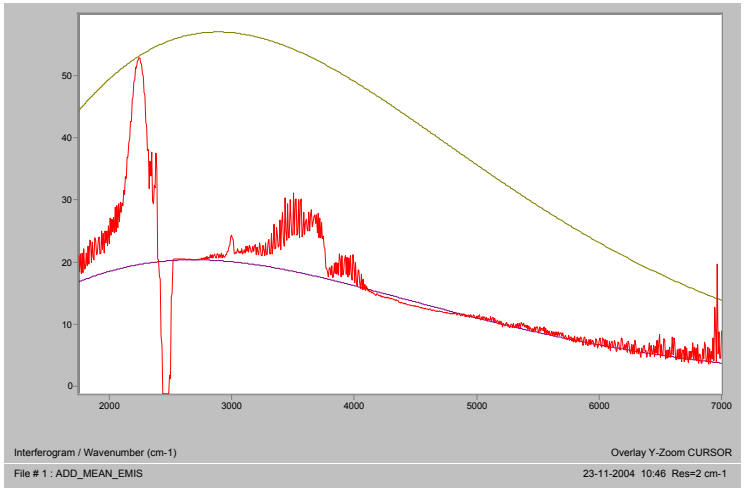
CO målt/beregnet

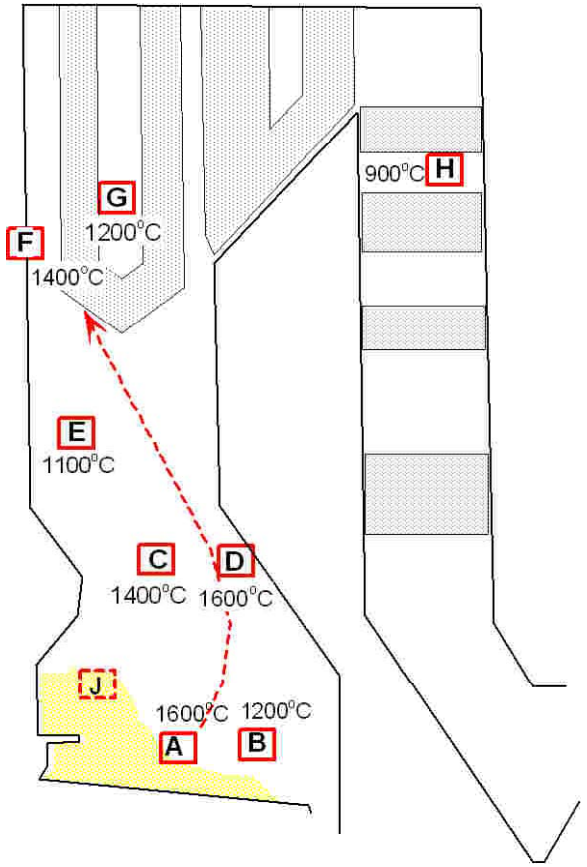


H_2O målt/beregnet

IR SPEKTROSKOPI, Kraftværk

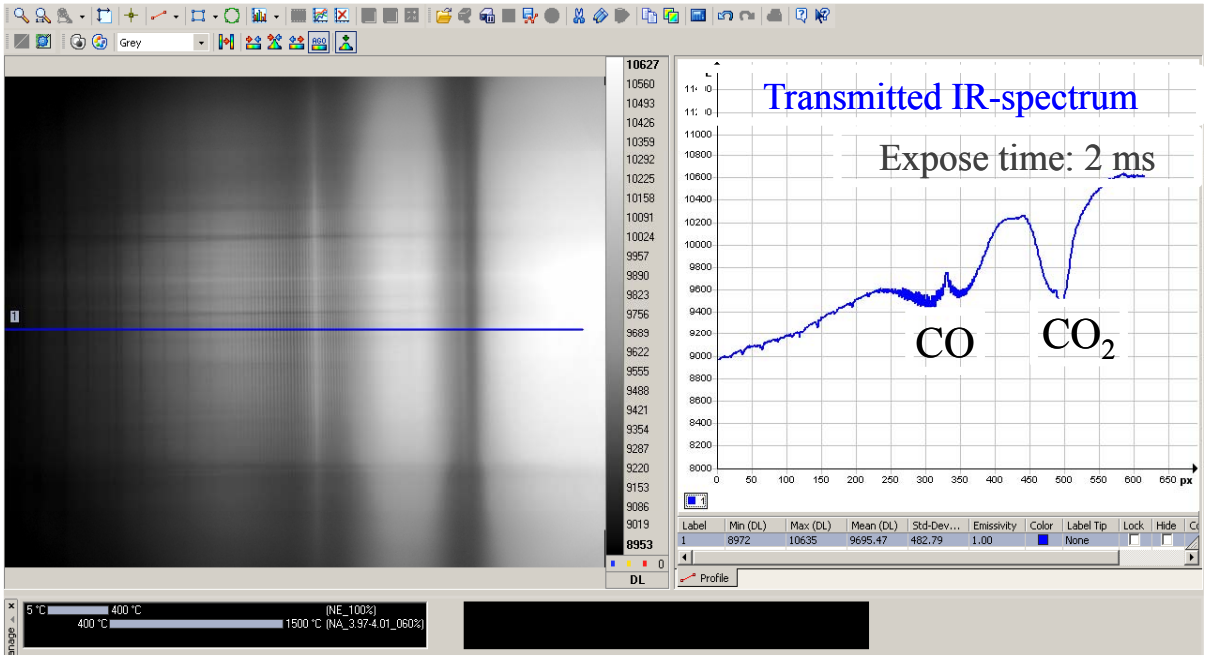






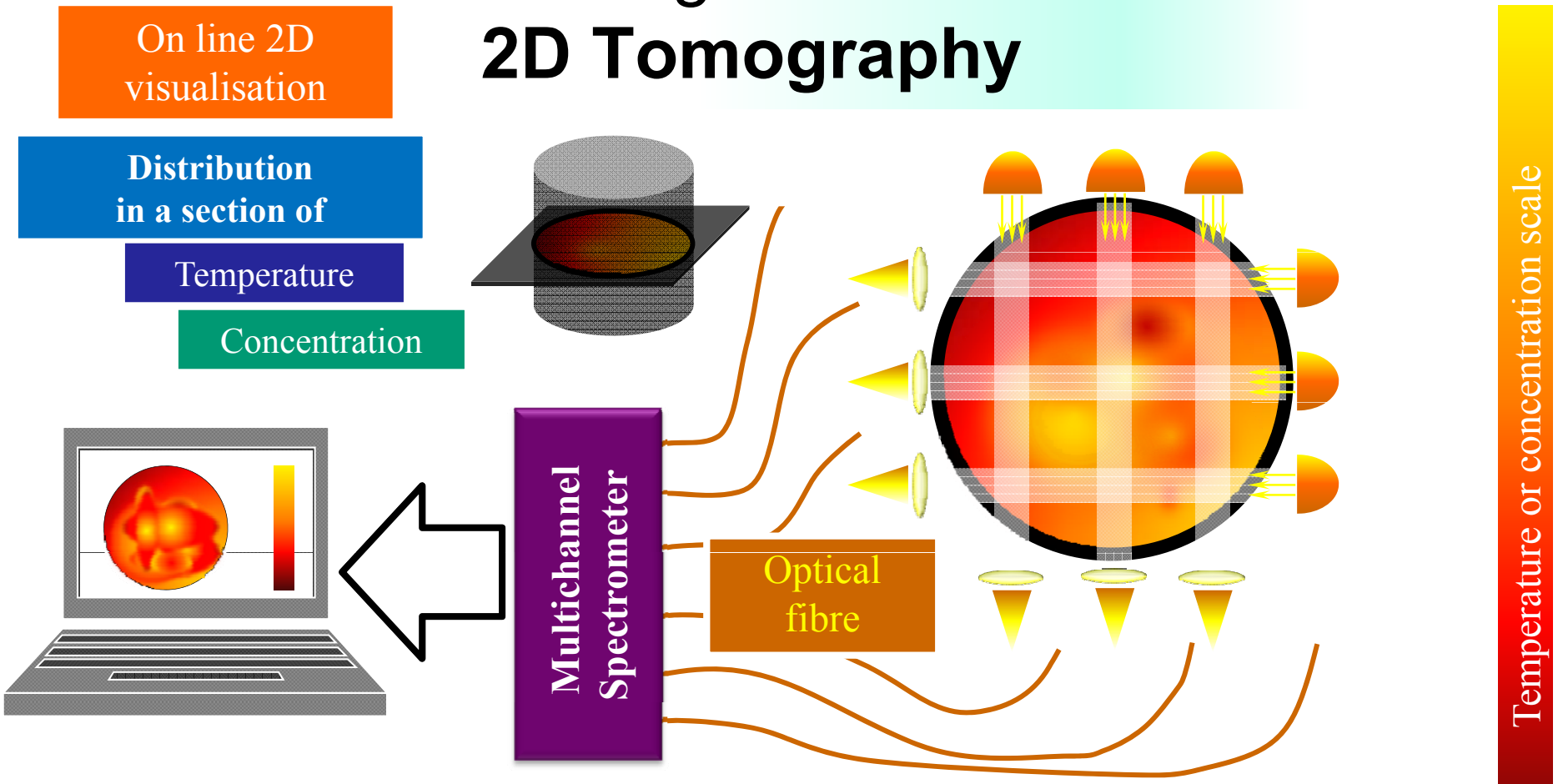
New diagnostic tools:
Fast IR imaging

- ***In situ* fast IR absorption/emission spectroscopy**
  - **ACTON spectrometer + CEDIP Camera (InSb 640x512 array)**
- It allows to accomplish measurements within a few microseconds
  - » This gives an opportunity to trace the development of a combustion process in time providing useful information for better understanding of combustion phenomena



up to
7 µs

New diagnostic tools:
2D Tomography



- 2D Tomography of e.g. hot gas inside of an exhaust pipe shows distribution of temperature or concentrations in a pipe section

Måling af gashastighed

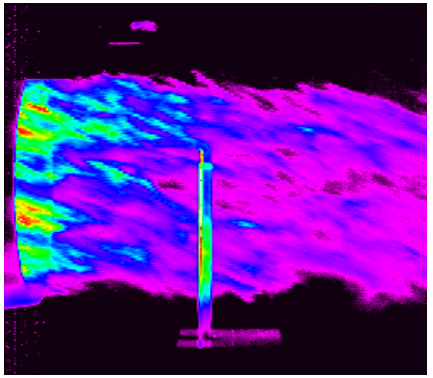
- **Laser LDA**

  (bedst afstande under 1.2 m

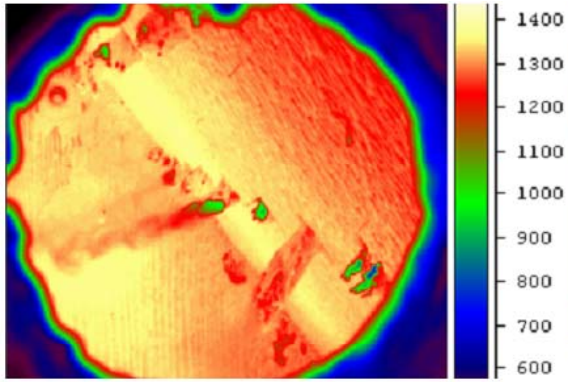
  dyrt udstyr)

- **Termiske strukturer**

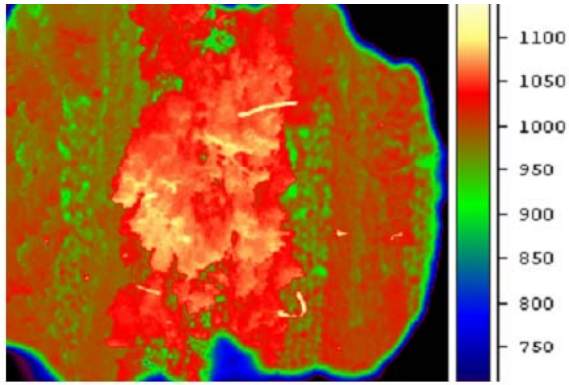
- **Analyse af billeder**



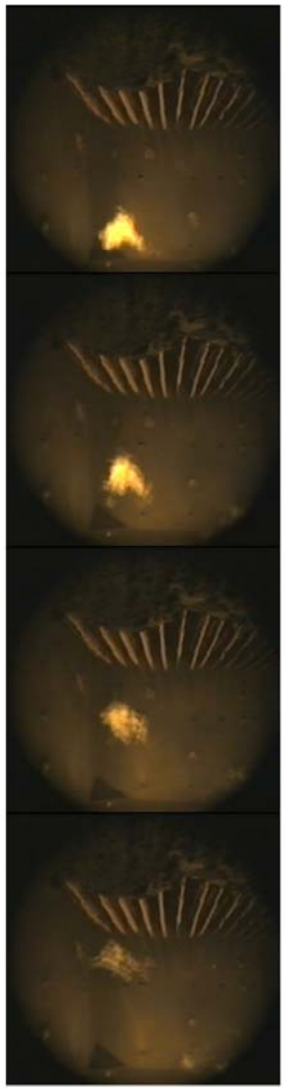
Udstødning flymotor



Støv i luft



Halmstrå/partikler



Konklusion

Termografi har mange anvendelsesmuligheder indenfor forbrændingstekning:

- **Overfladetemperatur**
- **Temperatur af brændsel**
- **Gør det muligt at ”se” i fyrrum**
- **Fastfryse / tidsopløse opblanding**
- **Se gasser mv.**